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Incubation

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Note: Hatchery registration and inspection in Ontario is performed by Agriculture Canada, Veterinary Inspector Directorate. Persons planning to operate a registered hatchery should consult with the district supervisor of the above service with respect to facilities, sanitary arrangements, shipping regulations, etc. The address is:

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Guelph, Ontario N1H 7Y7

ABBREVIATIONS

degree(s) Celsius	°C
degree(s) Fahrenheit	°F
gram(s)	g
millilitre	mL
ounce(s)	oz
percent	%
millimetre	mm
square centimetre	cm^2

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INCUBATION

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INTRODUCTION

Both the Chinese and the Egyptians are credited with originating artificial incubation procedures many centuries ago. The Chinese first used burning charcoal and the hot bed method in which decomposing manure furnished the heat, and the Egyptians provided heat from large clay ovens built in the area where the eggs were incubated.

On this continent, the first incubators were of the small, single-compartment type, which later became the sectional incubator consisting of several separate compartments, usually heated by hot water. Electric heating was introduced in 1923 and the first separate hatching compartment was invented in 1927. With improvement in incubation technology, fewer domestic poultry stocks were hatched on farms by natural incubation, resulting in a rapid increase in commercial hatcheries between 1930 and 1940. Further advancements in technology after the 1940's, ranging from automatic egg turning to completely computerized environments, resulted in hatcheries with incubator capacities of 1,000,000 eggs or more bringing about the inevitable decline in the number of commercial hatcheries in Ontario from approximately 350 in 1948 to about 40 in 1988.

For non-commercial uses, small incubators with egg capacities of several hundred or less are more convenient for those poultrymen interested in hatching only a few eggs, or poultry fanciers hatching special poultry breeds unavailable from large commercial hatcheries. They are also ideal for educational and display purposes.

The information contained in this publication is primarily intended for those interested in a small scale hatchery operation.

EMBRYONIC DEVELOPMENT

Only fertile eggs have the potential to hatch and produce offspring. The fertilized germ spot or blastoderm (Figure 1) spends about 24 hours in the warmth of the hen's body at about 41°C (107°F). During this 24-hour period, embryonic development is already taking place. The newly formed cell divides into numerous cells, finally appearing as a small whitish area on the outer surface of the yolk at the time the egg is laid. On breaking open a fertilized egg, the white germ spot resembles a large, round ring, differentiating it from the irregular-shaped, solid white mass of the infertile egg.

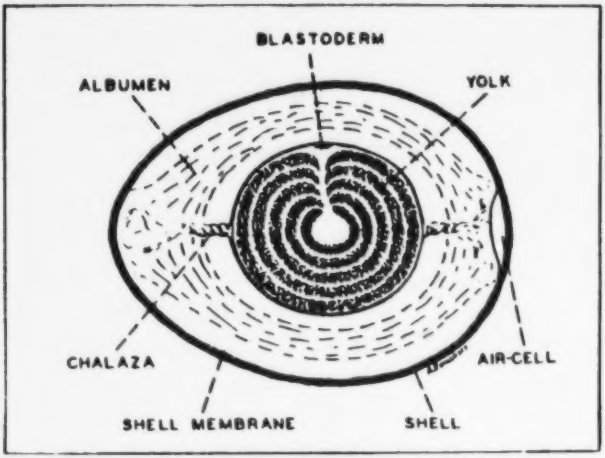


Figure 1. Cross-section of a fresh non-incubated egg

When the egg is laid and allowed to cool naturally, the embryo does not die, but development will cease when the temperature drops below 24°C (75°F). Development of the embryo will resume when the egg is placed in the incubator at 37°C (99°F). Storing eggs at temperatures of approximately 21°C (70°F) or above, however, will cause slow growth leading to the weakening and eventual death of the embryo.

During incubation, the main processes of respiration, excretion, nutrition and protection are performed by the extra embryonic membranes situated outside the embryo's body. These membranes consist of the yolk sac, amnion, allantois and chorion.

The yolk sac membrane is a layer of tissue growing over the surface of the yolk. Its walls are lined with special tissue which digests and absorbs the yolk material.

The amnion is a transparent sac, filled with colourless fluid, providing protection for the developing embryo.

Respiration by the embryo is made possible through the allantois. Blood vessels in the allantois supply oxygen to the embryo and remove carbon dioxide. The allantois stores excretion wastes and absorbs albumen, which is the food supply for the embryo. Its other function, is to supply calcium for the structural needs of the embryo. The allantois ceases to function when the embryo punctures the air cell and begins to breathe on its own.

The chorion is a layer of tissue which forms a barrier between the allantois and inner shell membrane during the later stages of embryonic development.

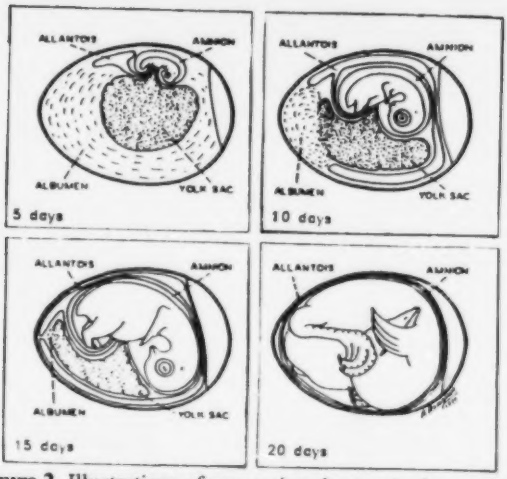


Figure 2. Illustrations of successive changes in the position of the chick embryo and its membranes during incubation

Events at Hatching Time of Chick

The beak should be underneath the right wing and pointing towards the air cell.

On the day prior to hatching, the embryo thrusts its head forward, piercing the inner shell membrane and entering the air cell.

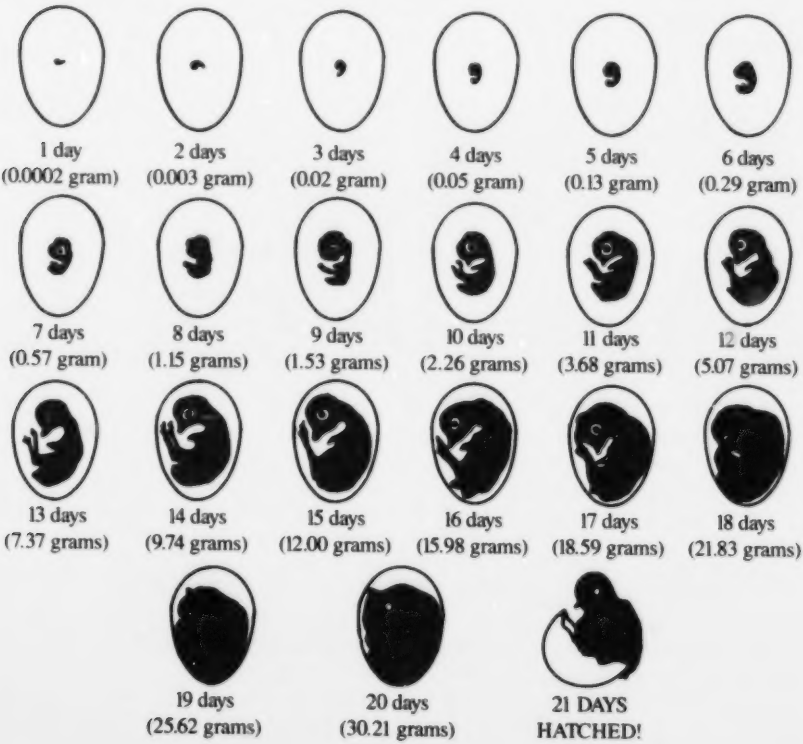
The chick then begins to breathe the air in the air cell, switching from allantois respiration to lung respiration.

On the 21st day, the chick escapes from its prison, breaking the shell with its beak and chipping it in a circular path. The shell wall breaks and the chick emerges.

Figure 3. Illustrations of the final stages in the hatching of chicken eggs

Important Events in Embryonic Development of The Chick

Before egg-laying	Fertilization Division and growth of living cells
Between laying and incubation	No growth; stage of inactive embryonic life
During incubation:	
First day:	Beginning of formation of head and eyes
Second day:	Beginning of formation of heart
Third day:	Beginning of formation of amnion, nose, legs, wings, allantois
Fifth day:	Formation of reproductive organs and differentiation of sex
Sixth day:	Beginning of formation of beak and egg-tooth
Eighth day:	Beginning of formation of feathers
Sixteenth day:	Scales, claws, and beak becoming firm and horny
Seventeenth day:	Beak turns toward air cell
Nineteenth day:	Yolk sac begins to enter body cavity
Twentieth day:	Yolk sac completely drawn into body cavity Embryo occupies practically all the space within the egg except the air cell
Twenty-first day:	Hatching of chick



Illustrations on Break-Out Appearance of Non-Incubated Chicken Eggs and Live and Dead Germs at Different Stages of Incubation

The common terms used to define eggs during incubation are infertile, fertile, live germ and dead germ.

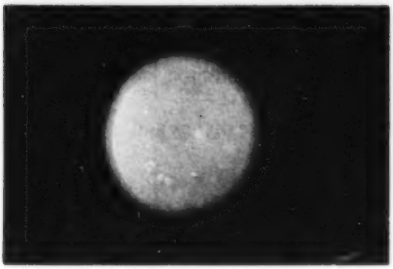


Figure 4. Infertile Egg

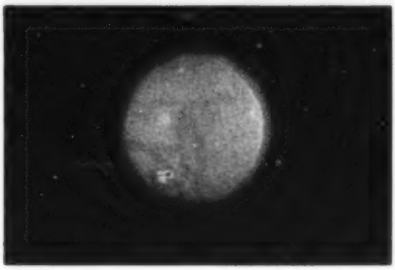


Figure 5. Fertile Egg

These are illustrations of hatching eggs prior to incubation. Note the heavy concentration of irregular-shaped, white material or protoplasm of the germ spot in the infertile egg. In the fertile egg, the protoplasm is more dense around the outer circumference of the germ spot and is larger and rounder than in the infertile egg. Due to formation of a cavity to accommodate the developing embryo, the central area is less dense, giving it a ring-like appearance.

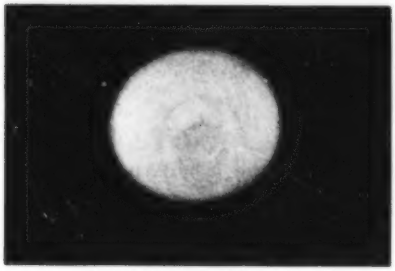


Figure 6. Live Germ — 2 days

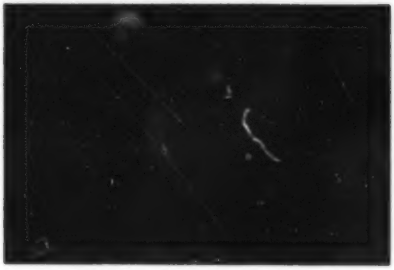


Figure 7. Dead Germ — 2 Days

After 2 days of incubation, the live germ appears as a small, reddish primitive streak or embryo in the center of the germ spot. Note that the germ spot has undergone a great deal of development since the start of incubation, as the white protoplasm spreads over the yolk surface.

Note the darkened spot in the center of the germ spot in the dead germ, and the complete disintegration of the white protoplasm, indicating the breakdown of the cells causing the embryo's death after 2 or 3 days of incubation.

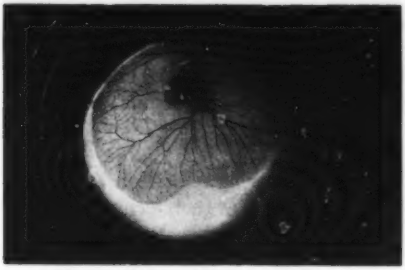


Figure 8. Live Germ — 5 Days

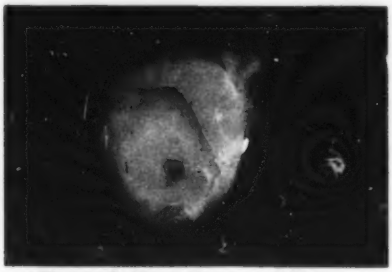


Figure 9. Dead Germ — 5 Days

Compare the yolk size prior to incubation with the greatly increased yolk size after 5 days of incubation.

In the 5 day live germ, the embryo appears as a dark reddish area surrounded by the allantois. The vascular network of blood vessels of the yolk sac membrane extend from the embryo over the greater part of the yolk area.

In the 5 day dead germ, the blood ring with the dark red spot nearby indicates the embryo has died. All the blood vessels have broken down and deteriorated.

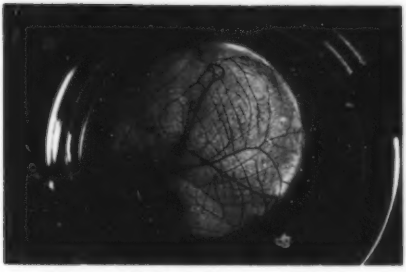


Figure 10. Live Germ — 9 Days

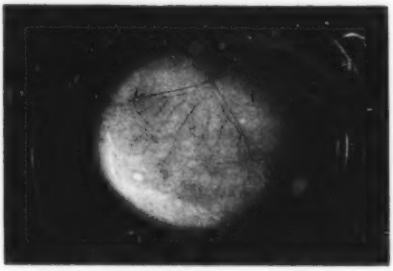


Figure 11. Dead Germ — 9 Days

In the 9 day live germ the eyes can readily be seen, as well as the outline of the beak and limbs. The yolk sac membrane has completely enveloped the yolk area and has become increasingly vasculated with blood vessels. The yolk has reached its maximum size at this stage of incubation. In the 9 day dead germ, a complete breakdown of blood vessels has caused the embryo to turn a dark purplish colour.

CANDLING OF CHICKEN HATCHING EGGS

Candling is carried out in a darkened room. The egg is held in front of a strong light which penetrates the egg, making it possible to observe the contents. The distinguishing differences between infertile and fertile eggs cannot be detected by candling prior to incubation, therefore, candling cannot be used at this time to assess fertility.

Differences are discernable between live and dead germs or infertiles when candling white-shelled eggs as early as three days after the onset of incubation and by six days for brown-shelled eggs. For those with little or no candling experience, it is customary to wait until the eggs have been incubated for a week. Very early dead germs and infertiles cannot be differentiated by candling. For all practical incubation purposes, they are just referred to as infertiles.

The air cell of the egg can be clearly seen when candling during incubation; the air cell continues to increase with time, indicating how long the egg has been incubated.

A small reddish area, with a network of blood vessels extending away from it, is visible in live embryos of fertile eggs after 3 to 6 days of incubation (Figure 12). If the embryo dies at this stage of development, the blood draws away from the embryo and the blood vessels deteriorate, leaving a red crescent shaped mark (Figure 13).

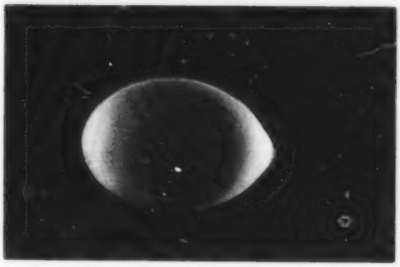


Figure 12. 5 day live embryo as seen by candling light

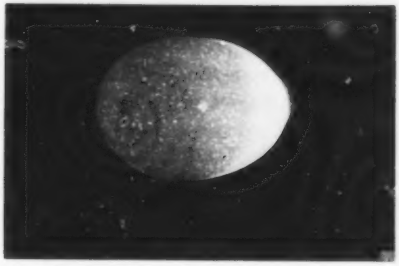


Figure 13. 5 day dead embryo as seen by candling light

In eggs incubated for 13 to 15 days, a live germ appears as a fairly large dark embryo with blood vessels radiating from it under the candling light (Figure 14). A dead germ at the 13 to 15 day stage of incubation is visible as a decomposed shriveled embryo lacking the presence of blood vessels (Figure 15).

Figure 14. 13 to 14 day live embryo as seen by candling light

Figure 15. 13 to 14 day dead embryo as seen by candling light

In hatcheries with limited incubator egg capacity, the infertiles and dead germs can be detected by candling and removed to make more efficient use of incubator space.

When candling eggs from other avian species, observations similar to that of chickens

are seen, with the exception of minor changes as to the stage of embryonic development of those avian species requiring a different incubation time period.

INCUBATION TIME FOR SOME COMMON AVIAN SPECIES

Chicken	—	21 days
Turkey	—	28 days
Duck	—	generally 28 days (exception, the Muscovy — 35 days)
Goose	—	30-32 days
Pheasant	—	24 days
Partridge	—	24 days
Japanese Quail	—	17 days
Guinea Fowl	—	26 days

SELECTION AND CARE OF HATCHING EGGS

The hatching percentage will be the highest if eggs are held at a temperature of 16 to 17°C (60 to 63°F) for not more than one week. Storage temperature should be reduced to 13°C (55°F) if eggs are being held for up to two weeks. Turning eggs during the holding period is not beneficial; in many instances, it has been shown that eggs stored for more than one week hatched better when held small end-up, which is contrary to the accepted traditional large end-up position. Relative humidity should be maintained at approximately 75% in the egg holding room. Prior to placing eggs in the incubator, they should be removed from the egg storage room and warmed to room temperature 23°C (72°F) for approximately 6 hours (Figure 16).

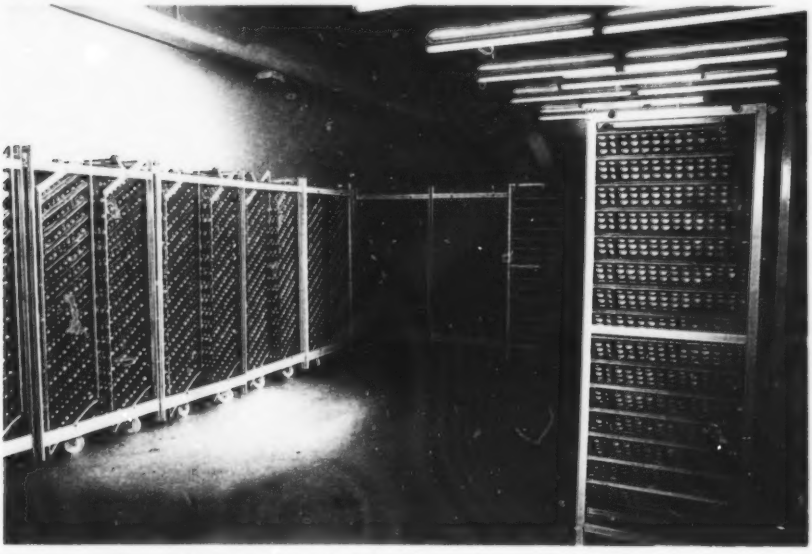


Figure 16. Typical egg-holding room of a commercial hatchery

Set only clean eggs. If eggs are soiled, it is preferable to clean them with a sandpaper egg brush. In instances where hatching eggs are washed, the temperature of the water must be 43 to 44°C (110 to 112°F). The eggs should be washed between two and three minutes only, and then fan-dried immediately. Improperly washed eggs may rot or explode during the incubation period. The problem of dirty eggs can be virtually eliminated if the eggs are gathered four or five times daily from nests supplied with fresh, clean litter.

Since many factors influencing egg quality characteristics are inherited, egg selection is of prime importance. Select hatching eggs that are uniform in size, shape and colour, with good sound shells. Do not set malformed, porous-shelled, double-yolked eggs or eggs with cracks. Shells that have a mottled appearance upon candling are not considered to have poor shell quality and can usually be set with good hatching results.

THE INCUBATOR ROOM

In the selection of a successful incubator room, factors such as heating, humidity, ventilation, and sanitation should all be considered. Optimum results can be expected if the room temperature can be maintained at between 21 and 24°C (70 and 75°F), with uniform humidity below the level that is required in the incubator. Good ventilation and a constant supply of oxygen to remove excess carbon dioxide from the environment surrounding the incubating eggs is necessary for the developing embryo. A continuous movement of fresh air in the incubating room at hatching time removes the stale air and obnoxious odors.

An incubator should never be placed near an outside wall or window, or in the path of direct cold air or sunlight (Figure 17).

Figure 17. Incubator room displaying a hatcher

INCUBATORS

Incubators represent the most important equipment in the hatchery process. Many kinds of incubators are manufactured; however, the general principles of all modern machines for commercial hatchery production are the same. Incubator setting capacity ranges from approximately 14,000 to 100,000 eggs.

During incubation, the hatching eggs are set vertically, with the large ends up in trays or flats in a setter and turned mechanically (setting period) until about three days prior to hatching (Figure 18). The eggs are then transferred to a hatcher (hatching period) in a horizontal position and not turned during the hatching process (Figure 19). Both setters and hatchers have forced-draft air circulation, automatic temperature, humidity and cooling controls.

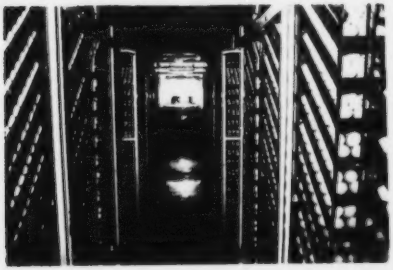


Figure 18. Inside of a setter

Figure 19. Inside of a hatcher

For small backyard poultry operators, classroom and demonstration purposes, there are small still-air machines on the market that can generally be purchased from local farm supply stores (Figure 20). Capacity of these incubators is approximately 12 to 200 eggs. The eggs are set in a horizontal position and are usually turned manually. This type of incubator may be used for the entire incubation period for any kind of eggs. The source of heat is a thermostatically controlled heating element or light bulb. Humidity is supplied in most cases by water in a pan below the eggs, and ventilation controlled by small air vents or holes. Most still-air machines have transparent plastic domes through which the incubation process can be observed.

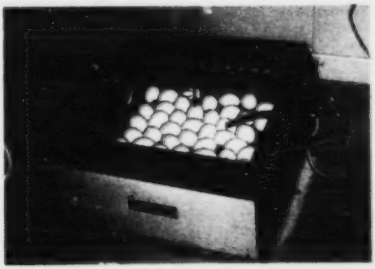


Figure 20. Small still-air incubator

THE PRINCIPAL FACTORS IN INCUBATION

The five main factors affecting incubation, listed in order of importance are: temperature, humidity, ventilation, position, and turning of the eggs. These factors are applicable to the incubation of chicken and turkey eggs.

Some factors to consider before purchasing an incubator:

1. Any incubator will produce better results when operating at capacity; therefore, egg capacity should be a factor;
2. The expected life and cost of all replacement parts;
3. Service and availability of parts;
4. Accuracy of controls, to keep temperature and humidity fluctuations to a minimum;
5. The amount of labour involved in operating the machine and carrying out a thorough sanitation program;
6. The guarantee.

Temperature

Hatching eggs should be warmed to room temperature, approximately 23°C (72°F), prior to setting. The normal development of the embryo is dependent on the heat being held within a very narrow range. In small still-air incubators, the temperature of the upper surface of the egg is higher than on the lower surface, while in large incubators, the air movement maintains the same temperature over the entire surface of the egg. For this reason, a still-air incubator must be operated at a higher temperature than a forced-draft incubator.

In small still-air incubators, a constant temperature of 39°C (102°F) is considered satisfactory to produce good hatching results. The temperature may vary between 38 and 39°C (100 and 103°F) without hurting the embryos as long as the temperature does not remain at either extreme.

These readings should be taken with the bulb of the thermometer level with the upper surface of the eggs, but not in contact with the egg shell. A standing thermometer will give a more reliable reading than a hanging thermometer. The temperature may rise one degree at hatching time without causing any reduction in hatch percentage.

In large incubators, the temperature, humidity, and speed of air movement are very closely dependent on each other, and since air speed varies in different incubators, it is impossible to state an exact operating temperature for all large machines, but generally it is around 37.5°C (99.5°F) for a setter and 37°C (98°F) for a hatcher. It is advisable to follow the manufacturer's instructions closely with regard to temperature and to ensure that instructions being followed are applicable to the model in question.

High temperatures for a very short period of time during any part of the incubation period will exert a greater adverse effect than low temperatures. Numerous factors may contribute to high or low incubator temperatures, such as:

— room temperatures too high or too low that affect the operating temperature of both large and small incubators. A large incubator placed near an outside wall, may have one section operating at a lower temperature than the other. Such a condition will result in one group of eggs hatching later than the others in the same incubator.

— an incubator thermometer not reading correctly.

— the failure of automatic equipment such as thermostats, cooling coils or automatic dampers.

— improper air circulation in the incubator, which may arise from a decrease in fan speed that is usually caused by low voltage or a slipping fan belt.

— incorrect spacing of filled egg trays in a partially filled incubator which may create improper air circulation, leading in turn to a rise in temperature.

— overloading an incubator for any one setting of eggs.

Humidity

During the incubation or setting period, hatching eggs should lose approximately 10.5 to 11.5% of their weight, due in part, to a loss of moisture. The amount of moisture in the incubator, controls the rate of evaporation from the egg. The evaporation rate is also related to temperature, air speed, and size of eggs; the smaller the eggs, the greater percentage of moisture loss. Too great a moisture loss from the egg in the early stage of incubation will cause the embryo to adhere to the shell, causing death. Insufficient evaporation will cause death from lack of oxygen in the air cell, since just prior to pipping the shell, the embryo is using oxygen at a faster rate than the rate at which oxygen can pass through the entire shell surface. The best guide to the correct amount of humidity in an incubator is the size and enlargement of the air cell during incubation (Figure 21), or the position at which the chick pips the shell (Figure 22). The degree of enlargement of the air cell should be determined by candling several eggs and estimating the average evaporation.

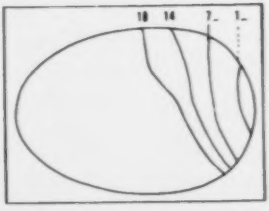


Figure 21. The enlargement of the air cell from 1 to 18 days of incubation

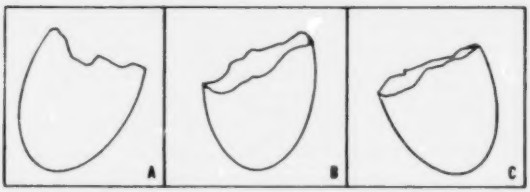


Figure 22. Appearance of shell from which chick emerged when: (A) Humidity too high; (B) Humidity too low; (C) Humidity correct

The amount of moisture in an incubator may be referred to in the operating instructions in terms of "relative humidity," which is a percentage of the moisture in the air at any given temperature. This can be measured by recording the reading from a wet-bulb thermometer. The "wet-bulb" reading will be expressed in degrees Celsius or Fahrenheit, the same as the temperature of the air. The relationship between wet-bulb readings and relative humidity is shown in Table 1.

TABLE 1. PERCENT RELATIVE HUMIDITY AT DIFFERENT WET-BULB READINGS

Wet-Bulb Reading		Relative Humidity at Air Temperature of	
		99° F (37.2° C)	100° F (37.8° C)
(°F)	(°C)	%	%
90	32.2	70	68
89	31.7	67	65
88	31.1	65	63
87	30.6	62	60
86	30.0	59	57
85	29.4	56	54
84	28.9	53	51
83	28.3	51	48
82	27.8	48	46
81	27.2	45	43
80	26.7	43	41

A wet-bulb reading is based on air movement, and for this reason, a wet-bulb thermometer cannot be used to determine the amount of humidity in a still-air incubator. The relative humidity for small incubators is usually stated as 60%. This percentage means little to the operator who does not have the equipment necessary to measure

relative humidity. A level water pan covering the floor of the incubator during the entire incubation period will generally supply sufficient moisture to give good hatching results, provided the moisture content of the air in the room is neither too high nor too low. Percent egg weight loss during the setting period can act as a guide in determining the correct humidity. This can be done by mass weighing the eggs at the start of incubation and again on the 7th and 18th day, and calculating the loss that occurred. Chicken eggs, for example, should lose approximately 4.5% and 11% during the first 7 days and the first 18 days of incubation respectively.

In large incubators, the temperature, air speed and humidity are intimately related, and the instructions issued by the incubator manufacturer should be followed closely. Better hatching results may be obtained if at hatching time the temperature is lowered and the humidity raised; however, this procedure can be followed only if separate hatching compartments are available. Lowering the air temperature will provide an additional increase in relative humidity to keep shell membranes moist during the hatching process.

Incorrect humidity may be due to a number of factors, the more important of which are listed below:

1. A wet-bulb thermometer reading incorrectly. Remove the wick to determine whether the thermometer is reading the same as the dry-bulb thermometer.

2. An accumulation of sediment on the wet-bulb wick. Change wicks often and use only distilled water in the reservoir.

3. In small incubators with humidity supplied by water pan evaporation, ensure that there is always an adequate amount of water in the pan, as the rate of evaporation is dependent on the humidity in the room. The lower the humidity in the room, the higher the evaporation and vice versa. During the hatching process, fluff settles on the surface of the water producing a film that causes a reduction in the rate of water evaporation necessary for optimum hatchability. To circumvent this, clean the water pan daily and replace with clean lukewarm water.

4. Ventilating an incubator to control temperature will lower humidity unless automatic humidifiers are being used.

5. Airflow in incubators is not uniform.

Ventilation

The free movement of oxygen, carbon dioxide and water vapor through the pores of the shell is important, since the developing embryo must be able to take in a constant supply of oxygen and release carbon dioxide and moisture. Oxygen content of 21% (present in air at sea level) and a carbon dioxide content not exceeding 0.5% in the air are considered optimum for good hatching results. It is difficult to make a definite statement about the required amount of ventilation for an incubator because of the number of other factors involved. For example, room temperature, room humidity, the number of eggs set, the period of incubation, and the air movement in the incubator all influence ven-

tilation requirements. It is known that ventilation problems are not the same in small incubators as they are in large incubators, where a large number of eggs are set in a very small space.

During the early part of the incubation period, ventilation in small incubators may be held to a minimum. However, during the hatching period additional ventilation must be supplied to reduce the carbon dioxide in the incubator. It is advisable not to increase ventilation until half of the hatch has been completed, since ventilating too soon will reduce the humidity. In large incubators, the manufacturer's directions should be followed, but the incubator operator must keep in mind that ventilating recommendations may not be applicable to every locality and every room condition.

If ventilation is used to control either temperature or humidity in the incubator, the control of the same factors in the incubator room becomes very apparent. At a room temperature below 18°C (65°F), ventilating an incubator will reduce both temperature and humidity. In a room with very high humidity, the humidity in the incubator cannot be reduced, regardless of the amount of ventilation applied. Since developing embryos have a greater tolerance to fluctuations in humidity than to changes in temperature, the primary concern is to maintain the correct temperature.

The main ventilation considerations may be summarized as follows:

1. Ventilation is more important in large incubators than in small incubators.

2. Ventilation is very important in any incubator at hatching time.

3. Ventilation in excess of the recommended amount may be applied to reduce temperature or humidity.

4. Insufficient ventilation at hatching time may result in embryo or chick death.

5. The amount of ventilation required may be altered by atmospheric conditions.

6. The appearance of chicks panting in a hatcher at normal temperature is an indication of a rise in the carbon dioxide content of the incubator air. Under such conditions chicks must breathe faster to obtain the required amount of oxygen and to eliminate the excess carbon dioxide. If excessive panting occurs, increase the airflow in the hatcher.

Position and Turning of Eggs

In small incubators, the eggs are maintained in a horizontal position during the entire incubation period (Figure 23), while in large incubators they should be placed in a vertical position with the large end up during the setting period (Figure 24), and in a horizontal position during the hatching period. In small incubators, the eggs move when turned, while in large incubators they remain in a stationary position on the incubator tray and the egg tray is turned through an angle of not less than 90° in opposite directions with each turning. The objective is the same in both types of incubators; namely, to prevent adhesion of the embryo to the shell membranes. Turning also ensures a complete contact of the embryonic membranes with the food material in the egg, especially in early stages of incubation.

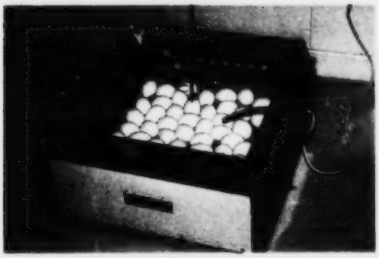


Figure 23. Position of eggs in a small still-air incubator

Figure 24. Position of eggs in large incubators

In small incubators, the eggs should be turned at least four times daily. It is advisable to leave some space on the tray to allow for moving the eggs forward on one turn and back on the next, thus making sure that all the eggs move. In large incubators, the trays are usually turned hourly with all the egg trays moving at one time (Figure 25). Eggs should not be turned in either large or small incubators during the hatching period. The greatest benefit from turning eggs is gained during the first week of incubation.

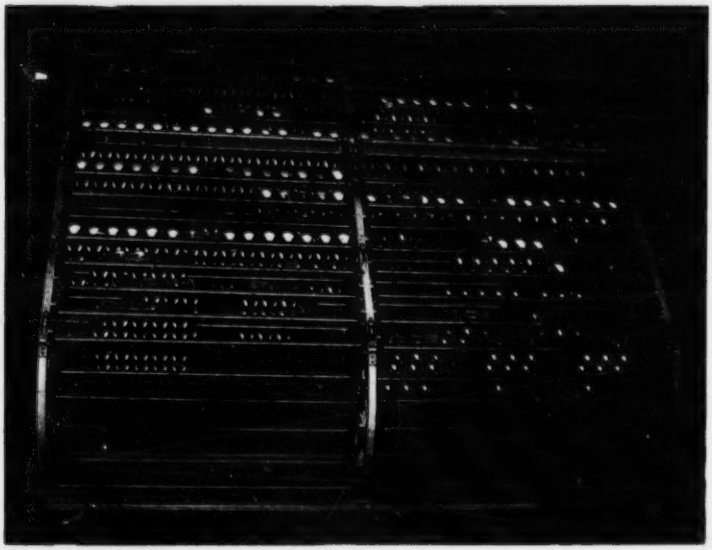


Figure 25. The turning of eggs in large incubators

Eggs should not be turned in a complete circle, as this has a tendency to rupture the allantois sac with resultant embryonic mortality. For good hatchability, eggs should be turned to a position at least 45° from vertical, then reversed in the opposite direction to a similar position. In the most recent models of incubators, eggs are turned through an arc of 150° and in a few models they are turned as far as 180°. The introduction of these newer methods of turning eggs has been an important aspect in improving hatchability.

INCUBATION OF WATERFOWL EGGS

The incubation period for Pekin and most domestic ducks is 28 days. The Muscovy requires 35 days. Canada and Egyptian geese require 35 days — all other geese 30 to 32 days (Figure 26).

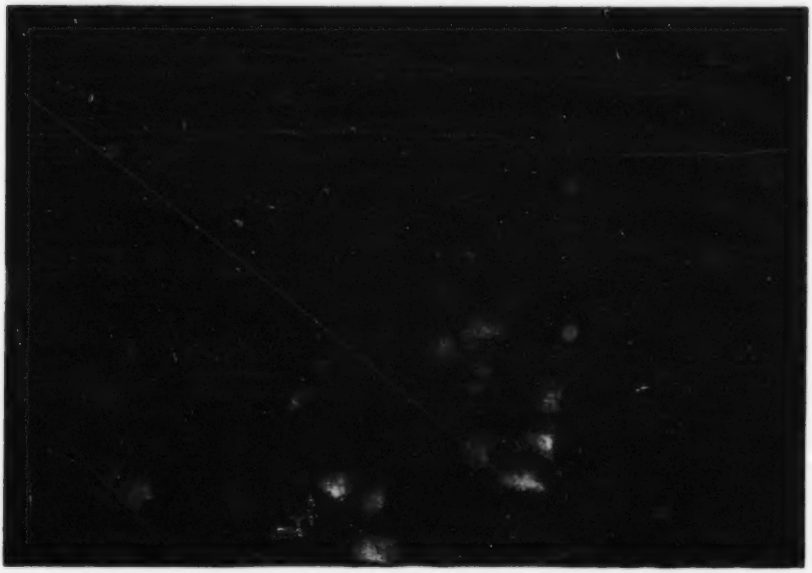


Figure 26. A hatching tray of ducklings

In small flocks, it is possible to incubate waterfowl eggs by natural means. A goose will cover 9 to 11 eggs and a duck 10 to 13 eggs. The Muscovy duck is a good setter, whereas most other duck breeds are not. A broody hen may be used to incubate waterfowl eggs and is capable of incubating 4 to 6 goose eggs or 9 to 10 duck eggs. The nest location should be such that the hen will not be disturbed during the incubation period. There should be a readily available source of feed and water. If hens are used to incubate waterfowl eggs, those hatching early should be removed from the nest as soon as possible and placed under a brooder. This will prevent the hen from leaving the nest before the completion of the hatch, or trampling some of the young if she becomes restless.

When hens are used for setting, it is necessary to add moisture. The eggs should be sprinkled with lukewarm water, especially during the latter part of the incubation period, and the nest and straw should be placed on the ground. This helps to increase the moisture. If ducks or geese have access to water for swimming, no additional moisture is needed. Where a setting hen does not turn the eggs, they should be marked on one side and turned 180° daily by hand. Usually the hen will move or turn the eggs.

Artificial incubation is used extensively for hatching waterfowl eggs. For a small number of eggs, small still-air incubators are common, whereas the large forced-draft machines are preferred for a large number of eggs.

Hatching eggs should not be removed from the cool egg-holding room and placed directly in the incubators. They should be warmed to room temperature first, approximately 23°C (72°F). In the case of duck and goose eggs, the prewarming period will take 8 to 10 hours. Placing cold eggs in the incubator will reduce the heat within the incubator until the freshly set eggs reach incubator temperature.

In the small still-air incubators, a constant temperature of 39°C (102°F) for duck and goose eggs is considered satisfactory for good hatching results. The temperature may vary between 38 and 39°C (100 and 103°F) without hurting the embryos if the temperature does not stay at either extreme. All temperature readings should be taken with the bulb of the thermometer level with the top surface of the eggs. The eggs in still-air machines are set in a horizontal position, and are turned 180° on each turn. Mark the eggs on the long axis as a guide in turning the eggs 180°. They should be turned alternately to the right and then on the next turn to the left or vice versa. Turn the eggs three to four times daily. The moisture requirements are usually considered to be the same for goose and duck eggs. A water pan slightly smaller than the incubator tray above should contain a piece of jute cloth in the water to increase evaporation. The water in the pan should be replaced every few days, otherwise a film will form over the water and reduce the amount of moisture that will be available to the eggs. In addition, the eggs can be sprinkled with lukewarm water twice a week up to the 25th day, at which time this practice should be discontinued. As soon as the eggs are pipped, the humidity should be increased. In addition to the water pan containing the jute, sprinkling lukewarm water around the outer area of the hatching tray will further increase the humidity at hatching time in still-air machines. **Do NOT sprinkle water on the eggs at this time.**

In the large forced-air machines, a temperature of 37.5°C (99.5°F) is usually recommended for both duck and goose eggs.

Duck eggs are set in the vertical position with large end up, whereas goose eggs are set in the horizontal position. In most forced-air incubators, the eggs are turned hourly. Duck eggs are generally turned through an angle of 90 to 94°, the same as chicken eggs. Goose eggs should be turned 160 to 180°. Unless the incubator is built for this greater degree of turning, the eggs should be turned by hand.

For the incubation or setting period (the first 25 days) the humidity reading on the wet-bulb thermometer should be 29 to 30°C (85 to 86°F) or 55 to 57% relative humidity. The eggs can be sprinkled with lukewarm water twice a week during the first 25 days, as recommended for eggs in small still-air incubators. After the spraying of the eggs has been carried out, the humidity in the incubators will rise. It is important to remove the excess humidity as soon as possible after spraying, so that it returns to 29 to 30°C (85 to 86°F) on the wet-bulb thermometer. This can be accomplished by manipulation of the controls, such as opening the exhaust vents. Excessive moisture during the first 25 days of the incubation period, in the case of either duck or goose eggs, may result in lower hatchability. During the pipping and hatching period, humidity should be increased to 33 to 34°C (91 to 93°F) on the wet-bulb thermometer or 73 to 79% relative humidity. This higher humidity during the hatching period keeps the shell membrane moist, making it easier for the duckling or gosling to emerge from the shell.

INCUBATION OF GAME BIRD EGGS

(Pheasants, Partridge, Quail, Guinea Fowl, Etc.)

Storage of hatching eggs prior to incubation is similar to chicken eggs for temperature and humidity. The majority of game bird producers hold hatching eggs at a temperature of 13 to 15.5°C (55 to 60°F) and a relative humidity of 70 to 75%. Best hatching results are usually achieved by setting eggs that are not more than one week old. Prewarming of eggs at approximate room temperature of 23°C (72°F) is recommended for 4 to 6 hours prior to setting.

In small still-air incubators, a constant temperature of 39°C (102°F) is generally recommended. Humidity is provided in a similar manner to that described in the "Incubation of Waterfowl Eggs," except that the eggs should **not** be sprinkled with water during the incubation period.

Temperature recommended in forced-air machines is 37.5°C (99.5°F) during the setting period and 36.5°C (98°F) for the last three days of incubation (the hatching period). Most game bird hatcheries operate the setters at 29 to 30°C (84 to 86°F) wet-bulb reading or 55 to 57% relative humidity.

As with chicken eggs, percent egg weight loss during the setting period is a very important criterion in achieving optimum hatchability. Usually 11 to 12% will provide the best results for most species. At the time egg pipping starts, humidity is increased to 32 to 33°C (90 to 92°F) or 75 to 80% relative humidity. This increased humidity keeps the egg shell membrane moist, thus facilitating the emergence of the chick from the shell. At the completion of the hatch, the humidity is lowered to cause the down on the chicks to become fluffy prior to removal from the hatcher. Make sure that the incubators are properly ventilated, so the embryos will not suffocate from lack of oxygen, especially near the end of the incubation period.

The thick shelled eggs of guinea fowl need special attention for humidity during incubation. As their incubation period is 26 days, they should lose approximately 12% of their original weight by the end of 23 days. On transferring to the hatcher, candle a sample of eggs to ascertain air cell size. As soon as the air cell drops to the position for the chicken egg on day 18 (see Figure 21 on Page 13) and pipping has commenced, increase relative humidity to 80%. If close adherence to this procedure is not carried out, hatching performance may be disappointing.

OTHER FACTORS AFFECTING INCUBATION

Egg Selection

Poor quality hatching eggs do not hatch as well as eggs of good quality. The term "quality" refers to the condition outside the shell, the condition of the shell itself and that of the contents. Eggs with inferior characteristics, as discussed in "Selection and Care of Hatching Eggs," should not be set.

Sanitation

Eggs used for hatching should be clean and stored in clean containers in a sanitary egg holding room. Eggs contaminated with bacterial organisms usually do not hatch well and

this poor quality is reflected in the chicks that do hatch.

Egg Handling

Rough handling of hatching eggs before they are set will increase the number of dead embryos, with mortality occurring between the 4th and 13th day of incubation. Also, jarring eggs during incubation may result in the rupture of the egg shell membrane and thereby lower hatchability.

Fluctuations in Storage Temperature and Humidity

Large fluctuations in temperature and humidity during storage will have a major adverse affect on hatchability. Refer to "Selection and Care of Hatching Eggs" for proper egg storage procedure.

Toxicity

If the interior of an incubator is painted or varnished, or if the trays are varnished, the percentage of hatch will be reduced, possibly by as much as 25%. This adverse effect disappears in about 30 days, suggesting that the ill effect is eliminated by oxidation of the paint.

This problem may be overcome without any reduction in percentage of hatch if the incubator is fumigated with formaldehyde gas at the concentration recommended for proper hatchery fumigation. The gassing should be done as soon as the paint is dry and the incubator is operating at recommended temperature and humidity for incubating eggs.

Automatic Equipment

The addition of automatic equipment in incubators has eliminated many of the past hazards. It must be kept in mind however, that such hazards may recur when automatic devices fail. During a hatching season all automatic devices, such as cooling coils, automatic dampers, tray turners, alarm bells, etc., should be checked at regular intervals. After an incubator is purchased, it is important to know how every part operates.

Breeder Flock Health and Age

A healthy breeder flock, females with a good rate of lay, mated to vigorous males, will usually produce highly fertile eggs that hatch well under good incubation practices. Hatching eggs from new breeder flocks (just starting to lay) do not hatch as well as eggs from those that have been laying for three to four months. Hatchability of eggs from old breeders nearing the end of their laying period also declines.

Nutrition and Heredity of Breeder Flock

A hatching ration should be fed to breeders about three weeks prior to saving eggs for incubation. The extra vitamins and minerals that it contains, as opposed to a laying ration, are essential for good hatchability. Sometimes, disastrous hatching results are experienced by small part-time poultrymen who are swayed by the lower priced laying ration. If the nutritional requirement of the breeder hen is not adequate, detailed attention to all other

factors, such as hatching egg care, incubation procedures, etc., are wasted in attaining optimum hatching performance with good chick quality.

Usually, the more remote the ancestry is within a breeder flock, the higher the fertility and hatchability. Inbred breeder flocks have a tendency to severely depress the expression of reproductive traits.

Egg Candling

Candling chicken eggs regularly during incubation, primarily on the 7th and 18th day of incubation, is generally recommended for small poultry producers and poultry fanciers. Egg candling will detect infertiles and early dead germs (Figure 27). Therefore, problems within the hatching flock can be corrected without waiting until the incubation period is completed.

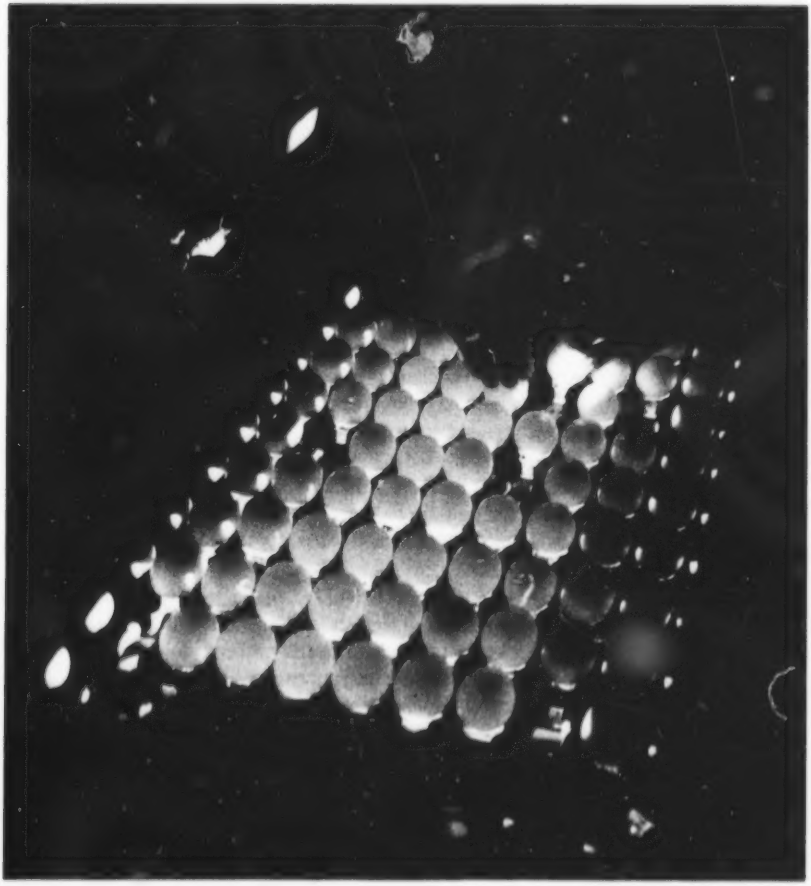


Figure 27. Egg candling

Hatchability of chicken eggs has greatly improved over the last 20 years and most commercial hatcheries have discontinued the practice of candling. The same hatchability results have not been achieved with turkey eggs and therefore, the common practice of candling them on the 14th and 25th day of incubation to remove infertiles and dead germs has continued.

Egg Cooling

It was previously thought to be beneficial to cool eggs during the incubation period, considering that the setting hen leaves the nest from time to time. It is now known that cooling eggs is not necessary and may even be harmful if practiced at the wrong time during the incubation period.

Improper Fumigation

Closely follow instructions outlined in "Fumigation Procedures." Excessive and improper fumigation can result in high mortality in developing embryos.

PEDIGREE HATCHING

Pedigree hatching is identifying the ancestry of day-old stock. This type of hatching involves more work and detail than is encountered in the usual methods of incubation. All eggs are marked with the hen numbers. The hen number should be written in the center of the large end of each egg. If some hens have only one egg at hatching time, it can also be an advantage to write the information on the small end of the egg.

When the operator is transferring eggs to the hatching trays, the eggs from each hen must be placed in a separate compartment so that the identity of the progeny may be recorded.

Figure 28. Arrangement of pedigreed eggs

Figure 29. Hatched pedigreed turkey poults

Frames which are partitioned into sections are placed in the hatching tray. Each section can be made into different-sized compartments by the use of metal dividers, depending on the number of pedigreed eggs for an individual hen. Then the entire hatching tray is covered by a wire screen. Eggs can also be pedigreed by placing up to four cradles made out of wire in the hatching tray. Usually the cradles consist of a wire mesh floor and sides in which the eggs can be allotted compartments using metal dividers. Then each cradle is covered with a wire mesh screen.

Figure 30. Turkey poults hatched from each compartment are the progeny from an individual hen

Figure 31. Turkey poult is wing-banded and recorded under the number of the hen which laid the egg

FUMIGATION OF INCUBATORS

The killing of bacterial organisms by formaldehyde gas is based on the concentration of the gas, exposure time, temperature, and humidity of the incubator. The chemicals potassium permanganate and formalin have proven to be the most effective method of destroying bacterial organisms in the hatchery. To accomplish the proper release of the gas, one and one-half parts (by volume) formalin is added to one part (by weight) of potassium permanganate. This will produce complete expulsion of the gas or fumigant. When the reaction is complete, a dry, brown powder will be left. If the residue is wet, not enough permanganate was used; if the residue is purple, too much permanganate was added.

CONVERSION TABLE

28.5 mL = 1 oz. (fluid)
28.5 g = 1 oz. (mass)

Concentration

The recommended concentration for effective fumigation is 53 mL of formalin added to 36 g of potassium permanganate per cubic metre of space to be fumigated,

or

1 1/2 mL of formalin added to 1 g of potassium permanganate per cubic foot of space to be fumigated.

Caution: Never add the permanganate to the formalin. Heat is generated when the two chemicals are combined, and care should be taken. Formaldehyde gas is generated quickly. Do not allow the fumes to get into the eyes. Personnel should use a respirator or wear a mask to avoid unnecessary exposure.

Time

It is not recommended to fumigate setters with hatching eggs in them, but if such treatment becomes necessary, **embryos between 24 and 96 hours of age should not be exposed to the above concentration of formaldehyde.** Hatching compartments should be fumigated after the eggs are transferred from the setter to the hatcher, again after the hatch has been taken off and before the refuse has been removed from the trays, and finally after the hatcher has been thoroughly cleaned. Do not fumigate chicks with this concentration of formaldehyde gas. Small still-air incubators should be fumigated after the chicks have been removed and prior to discarding the refuse from the tray and again after the incubator has been thoroughly cleaned.

Procedure

1. Make sure the temperature and humidity of the incubators are at normal operating conditions.

2. Measure the inside volume of the machine in cubic feet or cubic metres (length x width x height).

3. Close the ventilators, but leave the fans on.

4. Weigh the required amount of potassium permanganate into a wide enamelware or earthenware vessel large enough to accommodate the boiling and splattering action experienced when the formalin is added. Place the vessel and the permanganate in the area to be fumigated; then add the formalin.

5. Close the door immediately and leave closed for 20 minutes.

6. After 20 minutes, open the ventilators.

7. Open the doors of the machine for five minutes, leaving the fan on to allow more of the formaldehyde gas to escape, or neutralize it with a 25% solution of ammonium hydroxide equal to one-half the amount of formalin used. The hydroxide should be thrown directly on the floor of the machine and the doors closed. The formaldehyde gas will quickly be neutralized.

Continuous Fumigation of Hatcher

The greatest increase in bacterial organisms occurs during the hatching period. These can be reduced, but not completely eliminated, by slow release of formalin in the hatcher during the last 48 hours of the hatching period.

For continuous fumigation to be effective, hatching eggs should be fumigated at transfer time with the recommended concentration.

Place formalin in pan about 25 mm in depth, allowing 58 cm^2 of pan for each cubic metre of hatcher space, or a pan about 1 in. deep, allowing 30 in^2 of pan for approximately 1000 ft^3 of hatcher space. The pan should be placed in the open area of the hatcher in direct line with the airflow.

Place the pan of formalin in hatcher 48 hours prior to hatch completion. To overcome fluff deposited on the formalin, add more formalin about 24 hours before hatch is complete to increase evaporation.

When fan stoppage due to mechanical failure reduces the airflow, remove the pan of formalin immediately. If hatchers are only partially full, continuous fumigation is not recommended, as a reduction in airflow will create an excessive build up of formalin in the hatcher.

Effects of Fumigation

1. Properly carried out, fumigation should not affect hatchability.

2. Fumigation will only kill bacteria that is present on the surface of hatchery refuse, such as dead-in-shell that remain on the hatching tray. Fumigation will not kill bacteria inside the egg. Thus, it is important to dispose of hatchery refuse in such a manner as to avoid future contamination.

3. Fumigated refuse will minimize hatchery contamination during the cleaning operation.

4. Efficient fumigation along with other sanitary measures should control navel infection.

5. Fumigation is not intended to replace a thorough cleaning program.

SUMMARY OF SOME IMPORTANT FACTORS

1. Feed breeder flock hatching ration that is well fortified with essential nutrients.

2. Use healthy breeding stock.

3. Provide good egg-holding facilities.

4. Avoid holding eggs in storage for more than one week.

5. Prewarm eggs for 6 to 8 hours at incubator room temperature.

6. Set clean, good quality eggs.

7. Maintain correct incubation temperature, humidity and ventilation.

8. Turn hatching eggs frequently.

9. Maintain incubator room temperature between 21 and 24°C (70 and 75°F) with good ventilation and relatively high humidity.

10. Fumigate regularly.

11. Practice strict sanitation; cleanliness is very important for successful incubation.

Figure 32. The reward for successful incubation

TABLE 2. INCUBATION TROUBLE SHOOTING CHART FOR CHICKEN EGGS

SYMPTOMS OF TROUBLE	PROBABLE CAUSE	SUGGESTED REMEDIES
EGGS CLEAR No blood ring or embryo growth (Infertile & early dead germs)	1. Improper mating 2. Eggs too old	1. 6-10 vigorous males/ 100 hens 2. Eggs set within 7 days after laid 3. Keep hens in good flesh
EGGS CANDLING CLEAR But showing blood or very small embryo on breaking egg open (Early dead germs)	1. Incubator temperature too high 2. Badly chilled eggs 3. Low vitamin ration	1. Watch incubator temp. 2. Protect eggs against freezing temperatures 3. Feed hatching ration
DEAD GERMS Embryos dying at 12-18 days (Late dead germs)	1. Improper turning 2. Lack of ventilation 3. Faulty rations	1. Plenty of fresh air in incubator room and good ventilation of machines 2. Feed hatching ration
CHICK FULLY FORMED But dead without pipping	1. Improper turning 2. Heredity 3. Wrong temperature	1. Turn eggs at least 4 times daily 2. Select for high hatchability 3. Watch incubator temp.
EGGS PIPPED Chicks dead in shell	1. Low average humidity 2. Low average temperature 3. Excessive high temp. for short period	1. Keep wet-bulb temp. from 85-90° at hatch 2. Maintain proper temp. throughout hatch 3. Guard against temp. surge
STICKY CHICKS Shell sticking to chick	1. Eggs dried down too much 2. Low humidity at hatching time	1. Maintain wet-bulb temp. at 85° up to 3 days prior to hatching 2. Increase wet-bulb reading to 88-90° when eggs start to hatch

TABLE 2. Continued

SYMPTOMS OF TROUBLE	PROBABLE CAUSE	SUGGESTED REMEDIES
STICKY CHICKS		
Chicks smeared with egg content	1. Low average temp. 2. Small air cell due to too high average humidity	1. Proper operating temp. 2. Increase ventilation and lower humidity
CHICKS TOO SMALL		
	1. Small eggs 2. Low humidity 3. High temperature	1. Don't set eggs less than 54 g 2. Maintain proper humidity 3. Watch incubator temp.
LARGE, SOFT-BODIED CHICKS		
	1. Low average temp. 2. Poor ventilation	1. Proper temp. 2. Adequate ventilation
HATCHING TOO EARLY		
With bloody navels	1. Temperature too high	1. Proper control of temp.
DELAYED HATCH		
	1. Low average temp. 2. Eggs held too long	1. Proper temp. 2. Set eggs within 7-10 days after laid

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